# Standardized UXO Demonstration Sites

## Zonge 4-D TEM Acquisition System - *Open Field Scoring Record No. 38*

The 4-D TEM Acquisition System was demonstrated by Zonge Engineering and Research Organization, Inc.

### *4-D TEM Acquisition System*

*The 4-D TEM Acquisition System is an electromagnetic induction system that was demonstrated as a pushcart platform. Zonge Engineering and Research Organization, Inc. demonstrated the sensor in the Aberdeen Proving Ground Open Field Area. This technical sheet contains the results of that demonstration. This technical sheet is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Demonstration Sites Program.*

## Background

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground, Maryland and Yuma Proving Ground, Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the US Army Environmental Center. The US Army Aberdeen Test Center and the US Army Corps of Engineers Engineering Research and Development Center provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, and the Army Environmental Quality Technology Program.

## Demonstrator's System and Data Processing Description

The basic 4-D TEM acquisition system consists of three major hardware subsystems:

- GDP-32II Transceiver System
- Antenna Cart Subsystem
- GPS Navigational System

GDP-32II Transceiver Subsystem (not shown in photograph): The GDP-32II Transceiver Subsystem consists of a 3-channel high-speed digital data acquisition system together with a circuit board level fast switching NanoTEM transmitter (NT-32). The instrument transmits a bipolar current waveform at a pulse repetition frequency of 32 Hz. The transmitter is designed for rapid shutoff of current when working into relatively low inductance loads. With the antenna array that will be deployed at APG, the current shutoff time is approximately 5 $\mu$s. Secondary transients produced by nearby conductors illuminated by the transmitter field are sampled at a rate of 800 kHz and composited into 31 time windows over the time interval $1<t<2000$ $\mu$s.

Antenna Cart Subsystem: The cart-mounted antenna array consists of a single horizontal transmitter loop with an area of approximately 1 meter square mounted together with three mutually orthogonal receiver loops. Cart attitude (heading, pitch, and roll) is transduced with a digital compass/tiltmeter.

GPS Navigation Subsystem: Local positioning and geo-referencing of the Zonge NanoTEM system is accomplished using a Leica SR530 real-time kinematic (RTK) Global Positioning System (GPS). The Leica system consists of two dual-frequency geodetic quality receivers that are in radio communication with each other. A roving GPS antenna is mounted on the NanoTEM antenna cart.

The operator carries the controller along with the GDP-32II instrument package. The antenna has been located in a position where it does not measurably affect the TEM measurements.

DNT Data Processing Subsystem: The data recorded by the GDP-32II, the compass subsystem, and the Leica GPS system are processed using a software system designed around Geosoft's Oasis Montaj™. The data sets are merged based on time-stamps recorded in each data set. Raw data files are imported into Oasis Montaj™ through a proprietary preprocessing program (DNT Reduce). This program performs basic corrections for cart geometry (e.g., GPS antenna offsets), antenna parameters (e.g., transmitter moment, and effective receiver area), and merges the data with the GPS positions if available. DNT Reduce can act as a stand-alone program or can be executed from within Oasis. In either case, the program generates both text-based files (CSV) and/or a binary file that can be immediately imported by Oasis Montaj™ . The files output by Oasis Montaj™ meet the requirements for the raw sensor data that must be delivered at the end of the field demonstration. After importation into Oasis Montaj™ , standard features of Oasis Montaj™ together with custom Geosoft executable (GX) modules will be used to perform the following processing steps on the data acquired as a result of activities at APG:

- Component rotation from cart-fixed to geographic coordinate system (Custom Oasis GX)
- Generation of composite time windows (Custom GX)
- Background removal or leveling
- Map generation (Oasis)
- Target picking (Oasis/UXO)
- Target parameterization (DNT/Model)
- Target classification (DNT/Classify).

## Performance Summary

Results for the open field test broken out by size, depth, and nonstandard ordnance are presented in the table below. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. The results are relative to the number of ordnance items emplaced. Depth is measured from the closest point of anomaly to the ground surface.

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in the table have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

## Open Field Scoring Summary

| | | | | By Size | | | By Depth, m | | |
|---|---|---|---|---|---|---|---|---|---|
| Metric | Overall | Standard | Non-Standard | Small | Medium | Large | < 0.3 | 0.3 to <1 | >= 1 |
| RESPONSE STAGE | | | | | | | | | |
| $P_d$ | 0.45 | 0.50 | 0.40 | 0.40 | 0.55 | 0.50 | 0.60 | 0.45 | 0.05 |
| $P_d$ Low 90% Conf | 0.43 | 0.47 | 0.33 | 0.33 | 0.49 | 0.41 | 0.57 | 0.41 | 0.03 |
| $P_{fp}$ | 0.45 | - | - | - | - | - | 0.40 | 0.45 | 0.25 |
| $P_{fp}$ Low 90% Conf | 0.41 | - | - | - | - | - | 0.39 | 0.42 | 0.11 |
| BAR | 0.15 | - | - | - | - | - | - | - | - |
| DISCRIMINATION STAGE | | | | | | | | | |
| $P_d$ | 0.30 | 0.35 | 0.25 | 0.15 | 0.40 | 0.35 | 0.35 | 0.35 | 0.05 |
| $P_d$ Low 90% Conf | 0.26 | 0.28 | 0.20 | 0.12 | 0.36 | 0.29 | 0.30 | 0.29 | 0.01 |
| $P_{fp}$ | 0.30 | - | - | - | - | - | 0.30 | 0.30 | 0.20 |
| $P_{fp}$ Low 90% Conf | 0.29 | - | - | - | - | - | 0.27 | 0.29 | 0.07 |
| BAR | 0.05 | - | - | - | - | - | - | - | - |

Recommended Discrimination Stage Threshold: 50.00

*Note: The recommended discrimination stage threshold values were provided by the demonstrator.*